TITLE OF THE INVENTION

LINEAR COMPRESSOR AND CONTROL METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Korean Patent Application No. 2003-46207, filed July 8, 2003, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a linear compressor and a control method thereof. A linear compressor is widely used to compress coolant in a freezing cycle such as in equipment like a refrigerator, freezer, etc. The linear compressor measures the magnitude of a stroke of a piston, and controls an operation of the piston by applying a current to a driving motor of the linear compressor based on an analysis of the measured magnitude of the stroke.

Description of the Related Art

[0003] FIG. 1 is a cross-sectional view of a position detection sensor for a piston of a conventional linear compressor. As illustrated in FIG. 1, the position detection sensor comprises a bobbin 100, a sensor coil 101, a core support 102, and a core 103.

[0004] The bobbin 100 includes the sensor coil 101 inside, and the sensor coil 101 is connected in series to a first sensor coil 101a and a second sensor coil 101b each having the same inductance value, size, and number of turns. The core support 102 is made of non-magnetic material and supports the core 103 and is combined to the piston (not shown).

[0005] As the core 103 combined to the piston of the compressor reciprocally moves back and forth along an inner hole of the bobbin 100, a predetermined reactance is generated in the sensor coil 101 according to reciprocal movement of the piston.

[0006] FIG. 2 is a diagram of a conventional position detection circuit for the piston of the conventional linear compressor. As illustrated in FIG. 2, two serial sensor coils 101 are connected in parallel with two serial dividing resistors Ra and Rb, and a triangle pulse is input as a power source 105. A difference of voltages divided by the dividing resistors Ra and Rb is amplified by an amplifier 104 to detect a maximum output voltage according to the piston in which the core 103 moves back and forth starting from a center point between the first sensor coil 101a and the second sensor coil 101b. An analog signal processor 106 receives an output pulse from the amplifier 104 and detects the position of the piston through a predetermined signal process.

[0007] FIG. 3 illustrates an output pulse from the amplifier 104 in FIG. 2 according to the reciprocal movement of the piston of the linear compressor. As illustrated in FIG. 3, the output voltage from the amplifier (line "a") has a linear output property for the reciprocal movement of the piston. The position of the piston can be detected with the output voltage because the output voltage is proportional to the position of the piston.

[0008] However, the sensor circuit of the conventional linear compressor may vary the angle of slope of the linear graph according to external environmental conditions such as temperature and pressure. If the sensor circuit of the conventional linear compressor follows the linear property represented by a small angle of the slope like a line "b" due to the external environmental conditions, the piston controlled according to a steady operation when in a high cooling capacity may collide with a valve of a cylinder.

[0009] The conventional linear compressor uses a control method for controlling the reciprocal movement of the piston by determining a state of a load on the linear compressor based on a measured temperature or a measured driving current for a motor. The conventional control method of determining the state of the load on the linear compressor may respond to a change of the load on the piston late. Additionally it is hard to measure the temperature and the driving current accurately in a linear compressor, even if measuring points for the temperature and the driving current are properly selected.

SUMMARY OF THE INVENTION

[0010] Accordingly, it is an aspect of the present invention to provide a linear compressor outputting cooling power actively and controlling a stroke of a piston by determining state of a load on the piston accurately regardless of an external environment.

[0011] Additional aspects and/or advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

[0012] The foregoing and/or other aspects of the present invention are achieved by providing a linear compressor having a core combined to one end of a piston to detect a position of the piston reciprocally moving up and down, and a bobbin having a first sensor coil and a second sensor coil detecting the position of the core, comprising a controller determining state of a load of the piston by measuring an elapsed time for the core to exit and enter the bobbin from an inhale stroke through a compression stroke of the piston and controlling a position of the piston based on the measured state of the load.

[0013] According to an aspect of the invention, the core has a length shorter than one half of the length of the first sensor coil and the second sensor coil in series.

[0014] According to an aspect of the invention, the controller increases a top clearance of the piston if the amount of time taken for the core to exit and enter the bobbin increases greatly over a predetermined critical time.

[0015] According to an aspect of the invention, the linear compressor includes a first branch including the first sensor coil and a predetermined first dividing resistor connected in series, a second branch including the second sensor coil and a predetermined second dividing resistor connected in series, a power source applied to the first branch and the second branch, and a voltage comparator with voltage inputs applied to the first dividing resistor and the second dividing resistor.

[0016] According to an aspect of the invention, the voltage comparator has voltage inputs applied to the opposite terminals of each of the first sensor coil and the second sensor coil.

[0017] According to an aspect of the invention, the controller determines the state of the load on the piston on a basis of difference of time taken for the piston to be positioned near the bottom dead center making output of the voltage comparator zero (0) so as to control the position of the piston.

[0018] According to an aspect of the invention, the controller determines the state of the load on the piston on a basis of difference of time taken for the piston to be positioned near the bottom dead center making output of the voltage comparator zero (0), so as to control the position of the piston.

[0019] According to another aspect of the present invention, the above and other aspects may be also achieved by providing a control method of a linear compressor having a core combined to one end of a piston to detect a position of the piston reciprocal moving up and down, and a bobbin having a first sensor coil and a second sensor coil detecting the position of the core, including measuring time taken for the core to exit and enter the bobbin from an inhale stroke through a compression stroke of the piston; and controlling a position of the piston by determining state of a load on the piston on a basis of the time taken for the core to exit and enter the bobbin.

[0020] According to an aspect of the invention, the control method of the linear compressor further comprising forming length of the core to be shorter than a half of length of the first sensor coil and the second sensor coil connected in series.

[0021] According to another aspect of the present invention, the above and other aspects may be achieved by providing the control method of the linear compressor including increasing a top clearance of the piston if the time taken for the core to exit and enter the bobbin increases greatly than a predetermined critical time.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The above and/or other aspects and advantages of the present invention will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompany drawings of which:

FIG. 1 is a cross-sectional view of a position detection sensor for a piston of a conventional linear compressor;

FIG. 2 is a diagram of a position detection circuit for the piston of the conventional linear compressor;

FIG. 3 illustrates an output waveform from an amplifier in FIG. 2 according to reciprocal movement of the piston of the linear compressor;

FIG. 4 is a cross-sectional view of a position detection sensor for a piston of a linear compressor according to an embodiment of the present invention;

FIG. 5 is a block diagram of a position detection circuit for the piston of the linear compressor according to an embodiment of the present invention;

FIGS. 6A-6C and 7A-7C are input waveforms of a voltage comparator according to reciprocal movement of the linear compressor;

FIG. 8 is a control block diagram of the linear compressor according to an embodiment of the present invention; and

FIG. 9 is an output waveform of the voltage comparator according to a position of the piston of the linear compressor according to the embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0023] Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. The embodiments are described below to explain the present invention by referring to the figures.

[0024] FIG. 4 is a cross-sectional view of a position detection sensor for a piston of a linear compressor according to an embodiment of the present invention. As illustrated in FIG. 4, the position detection sensor comprises a bobbin 1, a sensor coil 2, a core support 3, and a core 4.

[0025] The bobbin 1 includes a sensor coil 2 inside, and the sensor coil 2 comprises a first sensor coil 2a and a second sensor coil 2b. The first sensor coil 2a and the second sensor coil 2b have the same inductance value, size, and number of turns and are connected in series. The core support 3 is made of non-magnetic material and supports the core unit 4 and is combined to the piston (not shown).

[0026] The core unit 4 comprises a core 4a having a short predetermined length. In this embodiment, the length of the core 4a is less than one half of the length of the sensor coil 2 comprising the first sensor coil 2a and the second sensor coil 2b. The core support 3 connects

the core 4a with the piston so that the core 4a can move according to the reciprocal movement of the piston.

[0027] As the core 4a combined to the piston of the compressor reciprocally moves back and forth along an inner hole of the bobbin 1, a predetermined reactance is generated in the sensor coil 2 according to the reciprocal movement of the core 4a within the sensor coil 2.

[0028] The core 4a moves reciprocally, centering around the first sensor coil 2a through a complete cycle of the piston. Further the core 4a is adjusted to reach near the second sensor coil 2b through a middle point between the first sensor coil 2a and the second sensor coil 2b (will be referred as a coil origin) when the piston arrives in a top dead center. Also, the size of the bobbin and the piston should be preferably configured so that the core 4a can come out of the bobbin 1 during an expansion stroke. Alternatively, this cycle may be reversed so that the core 4a exits the bobbin 1 during an inhale stroke.

[0029] If the state of the load on the linear compressor turns into an overloaded state, a stroke of the piston comes out of the bobbin 1 in an expansion stroke.

[0030] Such change of the state of the load can be determined by measuring time taken for the center point of the core 4a to exit and enter the bobbin 1.

[0031] A controller 13 as shown in FIG. 5, measures the time that the core 4a takes to exit and enter the bobbin 1 to determine the state of the load. In a case of overload, the controller 13 applies a high current to a driving motor of the linear compressor.

[0032] However, in case of an extreme overload, the top clearance of the piston may be increased by a partial amount of the load calculated and controlled by the controller when the change of the measured load is greater than a predetermined critical amount of the load. A reason for increasing the top clearance is that the overcontrolled piston may collide with a valve of the linear compressor if the state of the overload turns into the state of a steady load abruptly as the magnitude of the stroke of the piston during the overload increases. Accordingly, it is beneficial to prevent an abnormal operation of the piston by setting the top clearance of the piston to a value that is adequate over a broad load range.

[0033] The position of the piston may be controlled by determining the state of the load by measuring the time that the core 4a takes to exit and enter the bobbin 1. Hereinbelow, a

method to measure the time that the core 4a takes to exit and enter the bobbin 1 will be described. FIG. 5 is a block diagram of a position detection circuit for the piston of the linear compressor according to the embodiment of the present invention.

[0034] As illustrated in FIG. 5, the position detection circuit comprises a first sensor coil 2a, a second sensor coil 2b, a first dividing resistor R1, a second dividing resistor R2, a power source 10, a voltage comparator 11, a digital signal processor 12, and a controller 13.

[0035] The power source 10 applies power to a first branch having the first sensor coil 2a and the first dividing resistor R1 connected in series, and to a second branch having the second sensor coil 2b and the second dividing resistor R2 connected in series.

[0036] The voltage comparator 11 receives voltages taken from a terminal of each of the first dividing resistor R1 and the second dividing resistor R2 as a comparison signal V+ and a comparison signal V-, respectively. Also, the voltage comparator 11 may receive voltage taken from the opposite terminals of each of the first sensor coil 2a and the second sensor coil 2b.

[0037] The digital signal processor 12 transmits a rectangular pulse to the controller 13 according to an output of the voltage comparator 11, and then the controller 13 controls a driving motor (not shown) of the linear compressor on the basis of the rectangular pulse.

[0038] FIGS. 6A through 6C and 7A through 7C are input waveforms of a voltage comparator according to reciprocal movement of the piston of the linear compressor.

[0039] FIG. 6A represents a triangle pulse from the power source 10, and FIG. 6B represents waveforms input to a positive terminal and a negative terminal of the voltage comparator 11.

[0040] FIG. 6B represents the input waveform of the voltage comparator 11 when a center point of the upper core 4a (will be referred to as a core origin) passes a middle point between the first sensor coil 2a and the second sensor coil 2b (will be referred to as a coil origin), or when the piston reaches near a top dead center by a compression stroke. If the triangle pulse is applied from the power source 10, an inductance L2 of the second sensor coil 2b becomes greater than an inductance L1 of the first sensor coil 2a. Accordingly, the input waveform V- input into the negative terminal of the voltage comparator 11 has a time delay longer than the time delay of the input waveform V+ input into the positive terminal of the voltage comparator 11.

[0041] As illustrated in FIG. 6C, the digital signal processor 12 generates a rectangular waveform Vd having high level when the input waveform V+ of the positive terminal of the voltage comparator 11 is greater than the input waveform V- of the negative terminal.

[0042] FIGS. 7A through 7C are waveforms when the core origin is inclined toward the first sensor coil 2a from the coil origin. In this case, the inductance L1 of the first sensor coil 2a becomes greater than the inductance L2 of the second sensor coil 2b. Accordingly, the input waveform V+ input into the positive terminal of the voltage comparator 11 has a longer time delay. FIG. 7B illustrates input waveforms of the voltage comparator 11 in such case, and FIG. 7C illustrates a rectangular waveform Vd outputted from the digital signal processor 12 corresponding to the waveforms in FIG. 7B.

[0043] FIG. 9 is a waveform output from the voltage comparator 11 according to a position of the piston of the linear compressor according to this embodiment of the present invention.

[0044] As illustrated in FIG. 9, a waveform "c" has two zero points corresponding to the input waveforms illustrated in FIGS. 6B and 7B.

[0045] If the core origin of the core 4a passes the coil origin, the output waveform V_0 of the voltage comparator 11 has a second zero point, and it has a first zero point if the core origin of the core 4a comes out of the bobbin 1.

[0046] FIG. 8 is a control block diagram of the linear compressor according to an embodiment of the present invention. Hereinbelow, the embodiment of the present invention will be described in reference to FIGS. 4 through 8.

[0047] At operation S1, the time for the core origin of the core 4a to exit and enter the bobbin 1 according to an inhale stroke of the piston is measured, or the time that is taken for the output V_0 of the voltage comparator 11 having the first zero point to have the first zero point again according to the compression stroke is measured. Then, at operation S2, the state of the load on the piston can be determined based on the measured result.

[0048] In operation S4, the controller 13 checks the trend of the load. If the load decreased, the controller 13 will control the stroke of the piston to decrease accordingly in operation S3, however, if the state of the load is determined to be the overload, it is decided whether the

amount of the change of the load is greater than the amount of the predetermined critical load at operation S4 then the controller must adjust the top clearance of the piston in operation S5.

[0049] The controller 13 increases the driving current for the driving motor to increase the stroke of the piston if the state of the load is determined to be the overload at operation S6. However, the piston may collide with the valve as the piston becomes uncontrollable with a big stroke because the driving current for the driving motor increases when the increased amount of the load is greater than the amount of the critical load, or because a controlled velocity of the motor becomes lower than a changing velocity of the load when the state of the load turns into the steady state suddenly.

[0050] Accordingly, when the magnitude of the change of the load is great, it is desirable to change the magnitude of the stroke slowly by setting a target magnitude of the controlled stroke greater than the present magnitude of the stroke by some amount rather than to change the magnitude of the stroke of the piston abruptly by increasing the driving current for the driving motor. However, the collision of the piston and the valve may be prevented by increasing the top clearance by adjusting the target magnitude of the controlled stroke at operation S5.

[0051] The linear compressor according to this embodiment of the present invention detects the amount of the load and controls the cooling power based on the detected amount of the load.

[0052] Waveforms "c" and "d" in FIG. 9 are the output waveforms V_0 of the voltage comparator 11 when the external environmental conditions of the sensor such as the temperature and the pressure change. The waveform "d" illustrates that the zero point does not vary even if the external conditions changed compared to the waveform "c". Accordingly, it can be inferred that the external environment does not affect the zero points, which enables accurate determining the state of the load and controlling the position of the piston based on the zero points.

[0053] This embodiment provides the present invention a control of high quality on the stroke of the piston by determining the state of the load regardless of the external environment.

[0054] Although a few embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in this

embodiment without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.